

EVALUATION OF METHODS OF GENERATING OXYGEN
FROM SOLID CHEMICALS FOR
AIRCRAFT BREATHING SYSTEMS

Prepared By
Aero Medical Laboratory
Directorate of Research

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E.O. No. R-660-167

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

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I. PURPOSE

The purpose of this report is to evaluate the work already done in the field of chemical oxygen, and to estimate the work which lies ahead. Comparisons made herein deal with the gaseous, liquid and chemical means of supply of oxygen to aircraft breathing systems. The points for consideration are:

1. Weight
2. Volume
3. Performance
4. Hazards
5. Handling and Storage

II. FACTUAL DATA

1. Certain chemical compounds contain oxygen in a relatively unstable form so that the oxygen can be readily liberated by heat. These compounds can be stored over a period of years without depreciation of their capacity to yield oxygen.

2. Extensive research has been carried out by several countries in an effort to utilize these compounds as an oxygen supply for aircraft breathing systems. One principle involves "chelate compounds," which absorb and evolve oxygen according to the ambient concentration of oxygen. However, the oxygen is supplied at such low pressures as to fall far short of aircraft requirements. Another method relies upon the reaction of exhaled gases with alkaline oxides, such as potassium tetroxide. The percentage of oxygen in the supply line from this method is at all times much too low for high altitude use, as demonstrated in experiments at this Laboratory in 1948, reported in Memorandum Report MCRKED-660-122-H. Confirmation of these results appear in Naval Research Report 3230-17/49 AMM.

Technical Memorandum Report
WCRD 53-10
11 February 1953

3. The only successful attempts in such work to supply oxygen in quantity at the required rates have utilized the "chlorate candle." Sodium chlorate, at temperatures above 300°C., liberates oxygen. The chlorate candle is a mixture of iron filings and sodium chlorate, with additives to purify the oxygen. Combustion is started with an ignition cap, and some of the oxygen produced is used to burn the iron filings. This burning supplies heat to sustain the reaction.

4. As an example of performance, a chlorate candle of 92 cubic inches volume, weighing 2.18 pounds, yielded 100 liters of oxygen in 30 minutes. These data are compared with those of other systems in Table I.

TABLE I					
Style	Liters of Gas Per Lb. of Equip.	Liters of Gas Per Cu. In. of Equip.	Storage & Handling Features	Performance	Hazards
Chlorate Candle	45	1.1	Excellent	Erratic	Very High
High Pres- sure Gas	38	1.3	Poor	Good	High
Low Pres- sure Gas	24	0.7	Fair	Good	Low
Liquid Oxygen	143	143	Poor	Good	Almost None

5. At present, the demand for chlorates exceeds the supply by a considerable margin. Minor difficulties have been encountered in the elimination of impurities in the evolved gas and in prevention of clogging of the delivery path. These problems are not serious, however, and can be overcome by additional research. More significant problems warrant consideration here, as pointed out in reports from the U.S. Navy and the German Luftwaffe. These center about the explosive properties of chlorates.

6. Not only did fire result from gunfire tests of these candles conducted by the U.S. Navy, but spontaneous explosions have occurred as described in "German Aviation Medicine in World War II," Vol I, Ch V-B, quoted as follows:

Technical Memorandum Report
WCRD 53-10
11 February 1953

"The cartridges had a fundamental defect, the origin of which could not be found; the cartridges were likely to explode. One person was killed. This defect was the only reason that the chemical oxygen generator was not adopted by the Luftwaffe. It was used neither as servicing equipment nor as aircraft equipment, despite its high level of development.

"The first explosion, involving an aircraft oxygen system - which will be described later - occurred during a high altitude flight. The second explosion, in an autoclave..... caused only slight damage to the building. The I.G. Farben Gesellschaft (manufacturer of the cartridge) claimed, without proof, that the autoclave had been contaminated with oil.

"The third explosion occurred on the open terrain..... causing mild burns to the engineer in charge. Again, the I.G. Farben Gesellschaft was unable to explain the explosion. However, it was assumed in this case that glowing iron particles had combined with oxygen.

"Further testing was carried in the laboratory of the I.G. Farben Gesellschaft. Several hundred cartridges were discharged, and all, according to the report of the company, burned smoothly. After a cartridge had been developed which was thought to be satisfactory, the tests were resumed at Erprobungstell, Rechlin. After a long series of tests, it seemed that the cartridge was satisfactory, but one day the entire installation exploded, severely damaging the laboratory building. The stone walls.....were broken, the ceiling was lifted several centimeters, and the laboratory assistant conducting the tests suffered severe burns from which he died several hours later. The explosion could not be explained because the entire installation was destroyed. However, various theories were presented....."

A flight test was described in the same chapter:

"The cartridges were ignited and the pressure increased very rapidly; at 13,000 ft. the crew began to use oxygen. The cartridges heated to +340°C. Everything proceeded normally until there was a violent explosion at 20,000 ft. The aircraft was filled with thick smoke and the chemical oxygen equipment caught fire..... After the fire had been extinguished and the smoke had escaped, the extent of the damage could be estimated roughly. A gaping hole about one meter in diameter was in the port side. The wooden

Technical Memorandum Report
WCRD 53-10
11 February 1953

instrument panel of the test installation was partly burned. The first two ignited oxygen cartridges had exploded and their contents had been scattered throughout the fuselage. The frames of the leather seats were bent where parts of the casing had been thrown against them. The third ignited cartridge had burst but was still in its rack. The contents of the oxygen cartridges had covered all the inside of the fuselage and its contents, including the flying suits. The chemicals produced a very disagreeable burning on the skin of both engineers, who were slightly injured. One had a severe contusion of his ankle and the other had a slightly bleeding wound at his left temple which smarted very much because of chemicals sprayed from the cartridges.....The I.G. Farben Gesellschaft was also unable to explain the explosion."

7. Gunfire tests of chlorate candles carried out by this Laboratory in 1944 resulted in shattering and fire.

8. The U.S. Navy reported fire caused by gunfire tests of chlorate candles in a report numbered JC10-1 (830-79/47). In another report, TED No. NAM AE519029, the U.S. Navy made the following statements:

"On the second unit, the sealing disc again failed to puncture and again the safety blow out patch ruptured.....the oxygen evolved was sufficiently hot to initiate spontaneous combustion of the micarta bottom of the unit's insulating case. The flame soon took on the appearance of a blow torch. As the burning continued, much of the micarta and cork case was burned and considerable of the bottom of the brass candle container also burned."

9. In all reports of fires and explosions, nothing more than speculation is offered as to the cause. In 1951, the Manufacturing Chemist's Association, Washington, D.C., published a data sheet concerning chlorates. The report states that hazards exist when chlorates contact such substances as:

sulfur	sugars	ammonium compounds	sawdust
sulfates	alcohols	vegetable dust	lint
sulfides	solvents	powdered metals	paint
phosphorus	acids	oils and greases	paper

10. An impurity need not be intimately mixed with the chlorates. A trace of impurity anywhere in the system can set off a chain of explosions including cartridges not contaminated.

Technical Memorandum Report
WORD 53-10
11 February 1953

11. The above hazards exist at room temperature. Chlorate candles reach temperatures above 350°C., and operate at elevated pressures. These conditions multiply the likelihood of explosion many times.

III. CONCLUSIONS

1. Difficulties such as clogged delivery lines and faulty starter caps can be surmounted by further research. However, no amount of research can change the chemical properties of a compound. The instability is within the sodium chlorate molecule, as the chlorate radical tends to react with almost any impurity.

2. Powdered metals are mentioned on the list of dangerous impurities, and the chlorate candle requires a large quantity of iron filings, intimately mixed with chlorates. This gives some substantiation to the speculation on the part of I.G. Farben that an explosion was caused by reaction of oxygen with glowing iron particles.

3. Manufacturers would be required to insure that all operations in preparing and assembling the cartridges be carried out so as to preclude the possibility of impurities being introduced. No more opportune situation can confront the saboteur who wishes to render aircraft unsafe. A trace of sulfur so small as to escape routine analysis is enough to constitute danger. Even after analysis, lint and vegetable dusts may settle from the air into the materials. In the event of an explosion, the manufacturer cannot be singled out definitely as the responsible party, as any impurities may have been obliterated. The cause of explosions must be established before adequate precautions can be taken to prevent recurrence.

4. If research were to be continued and tests carried out on hundreds of cartridges without mishap, as was done by the Luftwaffe, no assurance could be presented that the next group would not explode.

IV. RECOMMENDATIONS

That active research in this field be suspended for a period of approximately eight months, pending receipt of information from Europe concerning chlorate candles.

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PUBLICATION REVIEW

This report has been reviewed and is approved.

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Technical Memorandum Report
WCRD 53-10
11 February 1953

APPENDIX I

REFERENCES:

- (A) Naval Research Laboratory Report 3230-17/49 AMM.
- (B) "German Aviation Medicine in World War II," Vol I, Ch V-B,
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- (C) Letter, 16 June 1944, from Chief, Aero Medical Laboratory to
Eldridge Reeves Johnson Foundation, University of Pennsylvania.
- (D) Report by Naval Research Laboratory, Washington 20, D.C.,
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- (E) Report by Navy Department, Bureau of Aeronautics, 20 August 1947,
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TED No. NAM AE519029.
- (F) "Chemical Safety Data Sheet SD-42, Properties and Essential
Information for Safe Handling and Use of Sodium Chlorate,"
adopted 1951 by Manufacturing Chemist's Association, Inc.,
246 Woodward Bldg., Washington 5, D.C.
- (G) Aero Medical Laboratory Memorandum Report MCREXD-660-122-H, dated
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Technical Memorandum Report
WCRD 53-10
11 February 1953

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